PHILOSOPHY OF A BIOLOGIST

By

LEONARD HILL

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By
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PREFACE

Herein is set forth the fuller statement of those scripts, which the author gathered together in fulfilling a request that he should read a paper to the British Institute of Philosophical Studies, a paper which has already appeared in the Journal devoted to these studies. His endeavour was to suggest to those interested in philosophy that modern science has brought us to the conception of a power eternal, infinite, unknowable, "the power behind the sun" of the Egyptian king Akhnaton, energizing all in the universe, the dead no less than the quick; a power equivalent to the purest conception of God stripped of all dogma and superstition; a power in all and through all, whence we came, of which we are a part, and whither we return after death; a power active in all atoms of matter composing the nebulæ, the stars, the dust and the living cell; a power determining every action and reaction in the eternal evolution of the universe, the earth and life upon earth. The mystery of a living cell is, then, neither less nor greater than

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that of a drop of water; ceaseless reactions to the environment occur in both. The author suggests, too, that the recent developments of neurology, such as the study of reflex actions by Sherrington and conditioned reflexes by Pavlov, by lifting the veil which has hung over the reactions of the nervous system, are becoming of fundamental importance in the guidance of education.

Science, having dispelled the superstitions of past ages, should keep us to a pure faith and free from any modern revivals of witchcraft. The great conjurors have never been excelled by the manifestations of spiritualists, and the supposed messages of those who have passed over are characterized by a triviality which corresponds with the intellects of charlatans who act as mediums. Such a book as the *Road to Endor* was of great service in showing how clever men confessedly tricked a whole community by methods which lead the credulous to belief in spiritualism.

While metaphysics, creeds, spiritualism, remain barren, the exact observations and operations of scientific research, applied, not to war at the behest of ignorant governments, but to peace, work wonders in saving life and extending happiness.

While this small book has been in the printers' hands some extensions of knowledge

have come under the author's review which require mention in this preface.

Of the two entities of which the universe is conceived to be constructed, radiation and matter, the former consists of a group of waves, the latter of electron-waves and proton-waves. We know next to nothing of any of these waves, but they all possess a definite wave-length. "For the rest all the properties of the waves are embodied in mathematical formulæ which tell us with exquisite precision how the waves will behave under given circumstances, but can never tell us what they are. The formula which describes radiation fits the facts, not so the formula for electron-waves. The objects it represents may have either a positive or negative amount of energy of motion—an electron moving with a negative amount of energy is a mere absurdity. Such a transformed electron cannot be regarded as a proton, because the waves can change their energy from positive to negative and back again, but electrons cannot change into protons and back again" (Jeans). To get over this difficulty Dirac now supposes all positive electricity to be a deficiency of negative charge, and the proton to be the vacant chair of an absent wandering electron. When an atom is bombarded with powerful radiation, and an electron is driven out, the atom becomes short

of one electron and so positively charged. When an electron gives up energy and comes back to the vacant chair, there is, as it were, an annihilation of an electron and a proton. Free electrons wander everywhere through space and their return to vacant chairs in atoms is the source of energy of the stars. We are able, says the astronomer, to notice only departures from uniformity in the universe, the electrons which are displaced from atoms and the vacant places they have left behind. So appeared to Prospero, "like the baseless fabric of this vision, the cloud-capp'd towers, the gorgeous palaces, the solemn temples, the great globe itself."

In the vast ages of geological time it is recognized that great catastrophic events are cyclical. At intervals of millions of years continents sink into oceans; then sediments are deposited on ocean floors and become in time miles thick; next seas begin to retreat and mountains to rise; the sediments come up and appear in mountain ranges folded and overthrust; floods of basalt flow out through cracks rent by earthquakes. The cause of catastrophic cycles is traced to the heat evolved by radio-active material in the basalt which is so blanketed by the crust of the earth, that finally the basalt liquefies, and because liquefied, expands and lessens in density. Hence arise vast

disturbances ending in cooling of the basalt by the ocean, and a period of relative quiet follows (J. Jolly). An association, too, has been traced between volcanic and sun-spot activity. The deeper layers of mother earth are heaved up by the magnetic attraction of the sun. With sun-spot activity occur magnetic storms to which we, without the aid of recording instruments, are insensible.

The earth's crust is thus never still and Greenwich time is out of reckoning each year by a fraction of a second because Greenwich itself is moving its position. With the movements of continents climates change and living forms evolve, so that life persists under changed conditions.

In regard to the synthetic power of living cells, and the possible origin of life, it is of great interest to note that synthesis of carbon dioxide into sugar is brought about by photochemical action when this gas is attached on the surface of a very fine powder, this being held in suspension in water having an electro-positive charge. The powder used is one composed of ferric oxide deposited on kieselguhr to increase surface action and containing one and a half to two per cent of thorium oxide. On exposure to light the electro-positive charge lessens until the powder flocculates and deposits. If the radiation is then stopped the

electro-positive charge is restored and the powder comes back into suspension. This "poisoning" of the powder is due to setting free of oxygen, and being reversible, the production of carbohydrate is made continuous by suitable alternation of light and darkness. The red end of the spectrum is most active in producing this synthesis and the optimum temperature is about 31° C. Temperatures higher than this flocculate the powder. Here we have, then, a working model giving similar results under similar physical conditions to those produced by the green plant (E. C. C. Baly).

One other point—in many chemical reactions, obeying what is called the Mass Law, the total number of molecules in an active condition and able to undergo change bear a constant proportion to the remaining number of unchanged molecules. The same thing holds good for a population of bacteria; at any one moment only a section are liable to attack by a disinfectant, the total number of vulnerable individuals being a constant proportion of the survivors. There is, then, some rhythm of activity which affects the killing of bacteria by a disinfectant, just as it affects, say, molecules of cane sugar undergoing hydrolysis.

I am indebted to our great astronomers and physicists whose views I have cited and tried to bring in touch with biological science.

PHILOSOPHY OF A BIOLOGIST

With the progress of science we become more and more aware of the undiscovered, and of our feebleness to visualize or express what is dimly known to us. Geologists estimate that man evolved some 1,000,000 years ago on an earth which astronomers say is some 2,000,000,000 years old. Caution is required in accepting such figures, for we must remember how far out Lord Kelvin was in estimating the age of the earth before the discovery of radium. Man has been civilized for some 5,000 years, and Galileo, with his telescope and revolutionary ideas, lived some 300 years ago. There may be, we are told, a million million years before the sun grows weak and the earth becomes farther from the sun so that all life freezes. Long before this man may use up the metals available for his machines, and those ready sources of energy now so wastefully used, by which he at present multiplies and swarms in cities. In such case he will return, through

birth control or famine, or both, to a simple, uncrowded pastoral existence. There is little likelihood of his being able to use atomic energy other than that which reaches the earth as sun radiation and is available directly, or as energy stored in water power, wood, coal and oil.

Research in the laboratory is based on simple relations between cause and effect, and the scientific knowledge so gained hour by hour, is vastly extending inventions, by means of which men swarm in cities.

At the present time we have among us great astronomers and physicists, and every new experimental observation is tested as to whether it can be explained by existing theories, and if not, to find the modifications necessary to include it in the general theoretical scheme of natural processes. The formulæ of modern science are judged by their capacity for describing the phenomena of nature with simplicity, accuracy and completeness. It does not matter whether the formula corresponds to ultimate reality, for all progress is made and tested by experimental operations. "The essence of a physical theory is that it should be expressed in terms of concrete quantities of which we have experience and transcendental space is not one of these." An attempt is made to form a model which will supply a mental picture of what is taking place in the physical phenomena

under consideration. Faraday was so guided, there is not an algebraical symbol in his collected researches. The admitted incapacity of scientific men to grasp reality does not, therefore, justify anyone turning to table turning, spookery and other modern witchcraft. Theory, regarded as a tool not a creed, and based on operation and observation, has led astronomers, physicists and biologists over and over again to fresh operation and observation and new discovery. Spookery and telepathy have added nothing to human knowledge. "Better to live a crossing sweeper than die and be made to talk twaddle by a medium hired at a guinea at a seance."

"That which captivates their reasons and leads men of sincerity blindfold from common sense," wrote Locke, "will, when examined, be found to be some independent ideas of no alliance to one another, by education, custom, and the constant din of their party, so coupled in their minds, that they always appear there together; and they can no more separate them in their thoughts than if they were but one idea, and they operate as if it were so. This gives sense to jargon, demonstration to absurdities and consistency to nonsense, and is the foundation of the greatest, I had almost said of all, the errors in the world. Let custom from the very childhood have joined figure and shape to the idea of

God, and what absurdities will that mind be liable to about the Deity."

How rare a gift is accurate observation and how dependent on close attention. It was arranged that a clown pursued by a negro should rush into a Congress Hall filled with psychologists. The negro caught the clown and bore him to the floor and the struggle ended with a pistol shot, when the clown got up and rushed out of the hall pursued by the negro; the whole scene occupied less than 20 seconds and had been rehearsed and photographed in advance. Forty reports of the incident were sent in by the psychologists, 10 were quite false, 24 half legendary, and 6 only even approximately correct. How difficult then it must be to secure accurate evidence in the law courts from witnesses. Circumstantial evidences based on science such as finger-prints, blood tests, microscopic tests of writing, etc., are far more trustworthy. While the Assyrians some four or five thousand years ago accurately noted movements of the heavenly bodies and with the Egyptians laid the foundations of mathematics, the Greeks even conceived the motions of the solar system and an atomic structure, but it is only now that recent discoveries of electricity, X-rays, cathode rays, radio-active elements, the perfected methods of observation afforded by the modern telescopes, microscopes, spectroscopes, electrometers and

amplifying valves, etc., have, with the help of mathematical equations, such as Maxwell's which were, be it noted, founded on a model, so widened knowledge that we are the first to have evidence of an infinitely large and an infinitely small universe. The astronomers tell us that there is evidence of the existence of two million nebulæ, each spinning a universe similar to our own galactic universe; in this alone there exist some millions of stars. The whole galactic universe is spinning as a nebula spins. The velocity of rotation in the neighbourhood of the sun was roughly determined to be 200–300 kilometres a second, about a thousand times the rate of a train. Light travelling 186,000 miles a second, has taken 140 million years to reach us from some giant star just visible in the most distant nebula. In comparison with this inconceivably vast period of time it is noteworthy that the transit of an explosion from one molecule of nitroglycerine to the next is estimated to take some seven hundred thousand million millionths of a second, an infinitesimal time which bears a ratio to the times of human experience such as the latter bears to geological and astronomical time.

Bigger telescopes will reveal more and yet more nebulæ. If a circumference be set to this universe containing unknown millions of nebulæ, probably only about 20 per cent. so far are

visible, may not this universe be but a unit in something bigger? We are told that the number of the stars in the whole of the two million nebulæ is such that if stars were grains of sand, the grains would cover the whole of England hundreds of yards deep. Our earth is one-millionth part of one such grain, and we bother ourselves over questions of social rank. In estimating his position in the universe, "man," says Jeans, "had been guided mainly by his own desires and his self-esteem; long fed on boundless hopes, he had spurned the simpler fare offered by patient, scientific thought . . . henceforth he must reconcile himself to the humbler position of the inhabitant of a speck of dust and adjust his views on the meaning of human life accordingly." This astronomer tells us that radiation of the sun and stars is produced by the annihilation of atoms, that, as heat can only do work by becoming colder, the energy of the universe is running down; so vast are the cold regions of space that in the end energy will be dissipated into a universal increase of temperature negligible in amount. The present matter of the universe cannot, then, have existed for ever; an upper limit of its age has been assigned at some 200 million million years.

It is conceivable that radiation of shorter wave-length and higher availability than any known in the present universe might have

created such a universe by the running down of energy and might have crystallized into electrons and protons and finally formed atoms. Out of a chaos of radiation came the nebulæ, and out of these the stars, by condensation of whirling gaseous matter. "If we want a concrete picture of such a creation we may think of the finger of God agitating the ether, or be content to say creation is unknowable."

It is conceivable that there is an infinite supply of short wave-length radiation in internebular space which is evolving into matter, that the finger of God continues, and will continue for ever, to agitate the ether. Millikan and Lodge have suggested that scattered star radiation reconstitutes itself in interstellar space into matter. If so, the evolution of the universe may be without beginning or end.

The planets were not, as Laplace conceived, formed with the sun out of a whirling nebula, but out of a tidal stream of gas drawn out of the sun by the near approach of another star, a phenomenon so rare in the empty vastnesses of space that the earth, with the atomic structure and restricted conditions possible for life, may be, and probably is, unique.

All matter is now conceived of as resolvable into atoms, each comparable to the sun with its planets, but so small that the size of an atom bears the same relation to a drop of water as the

drop to the earth. Atoms of all elements more complex than hydrogen are, it is thought, composed of a highly condensed nucleus positively charged, consisting of hydrogen units or protons containing nearly the whole mass together with some negatively charged electrons. Around this nucleus spin other negatively charged electrons in various fixed orbits. Every atom can be activated by radiations coming from the sun and universe, but when not excited each atom of the lighter elements common on earth sinks in time to a state in which its electrons occupy orbits of lowest energy, one in each, and then continue in these orbits without dissipation of energy.

It has been shown that the various wavelengths of radiation are endowed with various quanta of energy, and that on irradiation of any substance the energy of any quantum of radiation, which is in tune with an electron, of an atom of the substance, is given up to it and this electron is then emitted—the photo-electric effect. There is emission of electrons only when quanta of the right value are available. "If water waves behaved like light quanta, the wavelets of an almost calm sea would throw a few selected pebbles as violently as the waves of a great storm throws them all." When electrons displaced from atoms, for example by electrical energy in an arc lamp, return to their

orbits, radiation is emitted, and here again the emission is only by complete quanta. The radio-active elements emit alpha particles, electrons and rays shorter waved than X-rays.

The pathways of alpha particles and electrons emitted by radium and the result on these pathways of a collision of an alpha particle with an atom have actually been photographed. By photographing the behaviour of a hydrogen atom, which is equivalent to a proton, when reflected by a calcite crystal, Dempster has been able to show that it is in a state of continuous motion at tremendous speed. The theory of atomic structure is so far confirmed by observation.

Different methods of experimental observation have led to the conclusion that both matter and radiation exhibit, on the one hand, the properties of undulatory phenomena, and, on the other, those of particles. Electrons are not merely point charges of electricity, but carry a train of waves with them, and these allow them to spin in certain orbits of a simple numerical relation and in no other; only one electron can occupy each orbit; an electron can jump only from one of the possible orbits to another; to effect the jump, a certain quantum of energy is required, neither less nor more will suffice. Inside the atom the electron is "all point," but, outside, it can expand to cover a volume much

larger than even that of the atom itself. There is strong indirect evidence that the atom as a whole has a wave as well as component waves for its individual electrons. The electron has electric charge and hence is influenced by electric and magnetic forces in a way that the quantum is not. It is constrained to move in a way determined by waves in its immediate neighbourhood and go where they carry it. Newton's laws are true for everyday life because a very short wave is indistinguishable in behaviour from a particle. "When the train of waves is taken into account, the classical theory of dynamics gives the requisite distribution of orbits in the atom" (J. J. Thomson).

We have been told that it is probably as meaningless to discuss how much room an electron takes up as it is to discuss how much room a fear, an anxiety, or an uncertainty takes up; that the quantum theory succeeds in keeping the universe in existence as a going concern, but it is difficult to form even the remotest conception of the realities underlying all these phenomena. "The train of waves determines the pathway the electron travels and the form of the waves is determined by events happening at a distance and propagated through space in the form of waves." However far from reality be such conceptions we know that electrons are given off by the hot

filament of the wireless valve, and that the forces in the oscillating circuit control their motion, that electrons are set free by light in photo-electric cells which make television and the "talkies" possible. They have become articles of commerce and the foundation of great industries.

We are told that when protons and electrons fall together and radiation is produced in the stars by the annihilation of atoms, the energy produced is "so great that the annihilation of one drop of oil would suffice to drive the *Mauretania* across the Atlantic.

"The atoms in a room," says Eddington, "are rushing about in all directions with a speed of a fifth of a mile a second; if the temperature could be raised to 20,000,000° C. they would be going at 50 miles a second. In the very core of the sun and stars the temperature is twice as high, and the substance consists of stripped atoms or ions with vast quantities of free electrons. The electrons of atoms forced off by X-rays combine again, to be forced off once more and so on. An X-ray on forcing out an electron is absorbed, when the electron combines again the X-ray comes out. Radiation of all wave-lengths finally reaching the surface through the screen of atoms is emitted into space." It is conceived that the main mass of the central region of the stars consists of im-

mensely heavy liquid supra-radio-active atoms with atomic numbers just above those of the known radio-active elements.

"Primeval matter," says Jeans, "has gone on transforming into radiation for millions of millions of years, until, by the rarest accident, gas consisting of the lighter and most inert atoms was torn out of the sun and condensed into a planet whereon the physical conditions became such as to make life possible." There is nothing to favour the view that life has reached the earth from elsewhere, and we know nothing of the primeval physical conditions which led to its formation, but we do know that life is only possible in complexes of atoms grouped together to form cells; in the case of viruses the complexes are too small to be seen under the highest power of the microscope, but these only exist in close relation with cells. The complexes of atoms which form living cells are relatively quiet and stable and have to be shielded from excess of radiation. All life is, however, kept going by the radiant energy of the sun, either directly received, or absorbed in the food. Electrons are forced out of the atoms of living cells by infra-red, light, and ultra-violet rays, by X-rays, and by gamma rays of radium. The latter given off by the radio-active material of the earth are used in concentration to kill cancer cells. Unfortunate girls who painted clock

dials with luminous paint containing a radium salt and sucked their brushes have died owing to the radium which, once absorbed, never left the body and ceaselessly continued to give off destructive rays. X-rays can be used for sterilization of the sex glands. In small doses they have been used experimentally for producing mutations, or abnormalities in germ cells. There are still shorter wave-lengths produced by cosmic annihilation of atoms; some of these have the power to penetrate through 16 feet of lead. Coming from inter-nebular space these cosmic rays knock electrons off millions of atoms in our bodies every second, with what physiological result we do not know. They must help to create a fresh configuration of the living cells from instant to instant, and possibly are one cause of the mutations which naturally arise from the germ cells of all varieties of living organisms. Mutations possibly may result too from the β and γ rays of potassium and other radio-active substances; if so, such rays are a pre-requisite of evolution (J. B. S. Haldane).

There is a blind newt living in dark cave pools in Austria, which has the vestige of an eye, viz., a group of pigmented cells buried under the skin. If one of these newts be exposed at regular intervals to red light such as that in a photographer's dark room, the group of pigment cells on either side of the head develop

into a fully formed eye with full power of vision. Exposure to full daylight does not have this effect. This is a striking example of the specific effect of radiations on living organisms.

The forcing of electrons out of atoms, that is the photo-electric effect, produced by the action of ultra-violet rays on the superficial living cells just under the horny layer of the epidermis of our skin, is the cause of sunburn. Some of the cells are killed and an inflammatory reaction results, consisting of flushed blood-vessels, and increased outflow of lymph and white corpuscles; this is followed by desquamation of the killed cells, production of new cells, and defensive pigmentation. A substance called ergosterol, existing in the epidermic cells in minute amount, when activated by the right wave-length and intensity of ultra-violet radiation, forms a vitamin necessary for growth and prevention of rickets. The effective wave-lengths are those shortest in natural sunlight (3,000–2,900 A.U.). These are intense enough when the sun is above 30° in the heavens and the sky is clear. Smoke and fog cut them off. The sensitivity of living organisms to visible rays is amazingly great.

Thus when photosynthesis takes place in a green alga (chlorella) only about four quanta of red, or green, light are required for each molecule of carbon dioxide assimilated.

Light rays falling on sensitive atoms in the liquid bathing the rod and cone layer of the retina cause an emission of electrons which stimulate the neighbouring cones, which in their turn excite afferent neurones and certain pathways in the cerebral cortex, and so produce perception.

Exact measurement has shown that as little as eleven quanta of radiation of green light suffice to stimulate the retina and provoke vision in a laboratory worker. Possibly one quantum suffices for the acuter vision of a savage. If this amount of energy were turned into heat and conserved without loss it would take some hundreds of million years to heat a gramme of water one degree Centigrade. Surely if telepathy were possible, nature would not have evolved an organ with such extreme sensitivity.

The primitive forms of life lived in the sea and the cells were bathed with sea water. In higher forms an internal medium, the blood, takes the place of the sea water. Life depends upon the maintenance of a balance of molecular exchanges between the cells and their environment. If the balance is disturbed so that, for instance, too many or too few water molecules, or potassium, calcium and sodium ions are passing to and from the blood and the tissues, life is imperilled; so too with oxygen molecules, or hydrogen and hydroxyl ions. There are "buf-

fer salts" present which maintain the balance and keep away excess of acid or alkaline reaction. Processes of oxidation and reduction go on in living organisms and these are associated with a loss and gain of electrons respectively. The reducing intensity of a solution is determined by the concentration of free electrons, the acidic intensity by that of hydrogen ions.

Between the cells and fluid medium of the body there thus goes on, then, a ceaseless interchange of ions, that is of molecules or complexes of molecules in an active state through loss or gain of electrons. It is noteworthy that potassium salts which are weakly radio-active are present in all living organisms.

The healing power of certain natural mineral waters are now being ascribed to the active ionic state of traces of the many elements which they contain, and we cannot say which of these traces is unessential. Electrical currents due to movements of electrons accompany every form of vital activity such as conduction of nerve impulse, muscular contraction and secretion.

A certain temperature is required for maintaining active the processes of life. The brain cells soon cease to function when the molecular dance is lessened by cooling or increased too much by heating. Continued monotonous warmth applied to the testes produces sterilization in the male.

In living processes, then, there is ceaseless play of radiation quanta or photons, electrons and molecules, but this play must not be too violent.

The physicist tells us of the amazing emptiness of the atom and, in consequence, of all matter. If the diameter of the nucleus be taken as 1, that of an electron is about 10 and that of the atom itself 100,000. The structure of a speck of dust sufficiently magnified might appear as the midnight sky, supposing the nuclei of the atoms and their planetary electrons were luminous. So open is the atomic structure that if all protons and electrons of the atoms in the body of a man could with the wave of a magician's wand be packed together the man would shrink to a speck.

A microscope magnifying a thousand times reveals the organism of suppuration called staphylococcus as a mere dot. Such a microbe contains millions of atoms, and each of these contains electrons acting as points, but potentially endowed with waves; waves of what no one knows. A non-filterable virus is too small to be seen under the microscope. It is comparable to a sphere 0·000025 mm. in diameter and containing perhaps some 500 molecules, and yet if one drop of blood from an animal infected with a virus disease be diluted ten and even a hundred million times and then one drop

of this dilution injected into another animal and so diluted again to a very high degree, this injection may cause the disease.

It is worth noting in this respect that in the very best vacuum which can be made there are estimated still to be some million million molecules per cubic centimetre, and that the purest water it is possible to distil, fluoresces in the ultra-violet rays and so shows impurity.

The chemist knows that all materials are resolvable into one or more of 92 elements and that these form a series of increasing complexity of atomic structure from hydrogen (one) to uranium (ninety-two). While two of the elements of the series have disappeared from the earth, a few such as silicon, aluminium and oxygen form most of its structure, at any rate on the surface. The atomic number of each element is given by the number of electrons (negative charges) spinning round the nucleus of its atom, the positive charge of the nucleus being of corresponding value.

Bombardment of atoms of certain elements by rays given off by radio-active elements causes their transmutation. Thus a helium atom may hit the nucleus of a nitrogen atom about once to a hundred thousand million shots, it then coalesces and hydrogen is ejected leaving, it is believed, an atom of oxygen with an abnormal

atomic mass of seventeen. No transmutation of base elements into gold has, however, resulted, and the dream of alchemists has not come true.

The radio-active elements themselves transmute, undergoing an evolution into other elements; in doing so a gram of radium emits 3·6 million million particles per sec. The physicist has succeeded in making this count. Each emission is spontaneous, cannot be predicted, nor any cause for it assigned; it can neither be stopped, nor controlled. We cannot tell whether a radium atom is going to break up today or a thousand years hence because we do not know what is going on in the nucleus of that atom. Such unknown and uncontrollable conditions we call chance. The ball thrown on a roulette table is really governed by initial conditions and obeys the laws of dynamics, but these conditions are beyond our control. So too with the behaviour of radium atoms. There is an interplay of which we are conscious only in very small part and we know nothing of the nature of the power behind that interplay which determines the result.

The difference of materials depends on arrangements of atoms, their grouping into complex molecules, and these again into crystals and colloids. The ceaseless play of radiation keeps

up a never-ending dance of all atoms, not only in each living cell, but in every particle of dust. The smallest particles seen under the microscope in a fluid medium ceaselessly dance, the molecules of a gas ceaselessly bombard the vessel containing them. A speck of dust or a drop of water is then to the seer neither less nor more marvellous and mysterious than the blue sky and sailing clouds, the flower, the nightingale and its song.

We know that the chemical elements are genetically related and fall into families; isotopes of the elements have been discovered comparable with individuals of a species. An element (lead) may arise by more than one line of descent. A pair of electrons together form something different from two electrons separately; on division something would be lost which could only belong to the whole (Eddington). Atoms repair themselves no less than organisms. An atom of copper which has lost an electron is no longer copper, the electron must be replaced. Loss and replacement ceaselessly go on both in living and dead substances. If the organisms of a species show individualism, so do atoms; chemical and physical constants are merely statistical averages of an infinite number of individuals summarizing a variable population. Atoms, no less than organisms, may retain their identity in spite of

ceaseless change. If a central control is ascribed to organisms, it cannot be denied to atoms.

Determination may be there beyond recognition. "Modern physical investigation," says J. S. Haldane, "of the atom and molecules seemed to be endowing them with something very like an individual life." "The similarities in behaviour," says Boycott, "between a hydrogen atom, an amoeba and a cat are, perhaps, really more significant than the differences." Smut's holistic conception of life as a unity, which maintains and asserts itself, no less applies to the atom.

The grouping together of atoms of elements forms substances quite different to these atoms. The behaviour of neither hydrogen nor oxygen suggests in the slightest degree the properties of water, nor of sodium and chlorine of common salt. Atoms of carbon, hydrogen and oxygen grouped in different ways form alcohol, ether, sugar and thousands of other substances, each of novel and individual behaviour. "Creative synthesis" and "emergent evolution" are terms applicable to these, no less than to living organism. Each instant activity of either atom or living cell is creative, the identity swings about a mean and is never the same for two moments. When a vitalist asserts that "a material thing has no evolution," and that

"science not only cannot discover, but cannot even represent the origin of life," we can answer that the whole universe is in evolution, and that we cannot discover or even represent the origin of matter. To the claim that "there is present in the living thing an active principle organizing it to carry out a set of self-interested purposive actions," science answers, Can we deny self-interested purposive action to the spontaneous emission of alpha particles from radium and the play of quanta and electrons? We do not know. It has been asserted by vitalists that crystals of a substance of the same size resemble each other completely, and grow by additions without change of chemical nature or release of energy, and that a drop of water is the same as any other drop, while individual organization and purpose are characteristic of organisms, But each atom of a crystal or of water is complex, active, evolving, unknowable in ultimate nature as is a living cell.

Individualism is not a general characteristic of living organisms, for just as electrons form atoms and atoms form molecules, and these crystals or other complexes, so there are innumerable species of lower animals which at times coalesce and break again into several or form colonies. There are the slime fungi exhibiting an astonishing rhythmic flow in canalized sheets of protoplasm; worms which segment into

chains of worms, the last link separating as the newest one forms. Plants can be propagated by cuttings and by pieces of root, or grafted together. Living tissue cells cultivated on suitable media grow and multiply indefinitely. Two-headed babies, Siamese twins and other monsters are born, and can easily be made by grafting embryos together; what is to be said about their personalities?

The discovery of X-rays has meant to physicists what the discovery of the microscope meant to biologists, geologists and chemists, for the use of these short wave-lengths has increased the range of observation ten-thousandfold. The molecule, large relative to the wave-length of the X-rays, has its characteristic shape imprinted by its scattering of the rays on a sensitive plate. From this imprint a picture of the molecule can be constructed by measurements and calculation. "The crystal," we are told, "shows all the exhilarating unexpectedness of an organism, subject as it is to principles of periodicity, attraction, repulsion, growth and structurally disciplined function." There is a persistent tendency of nature to arrange her molecules in ordered fashion. This obtains, not only in bodies hitherto called crystals, but also in cellulose, wool, hair, silk, nerve and muscle. The structure of cellulose has been revealed by X-rays in the cell walls of a living plant. We

are at the beginning of a new method of examining living substance.

When electrons and protons combine to form molecules and these to form larger particles, these exert attractions or repulsions on other particles which come within range. A single molecule owing to its mosaic surface may exhibit different kinds of specific actions. When oppositely charged particles come together a new configuration is presented able to make new attachments; a third particle becoming attached may or may not set free one of the others. Suppose an active particle, a catalyst composed of several molecular subunits fixes others and through reshuffling produces duplicates which separate, we then have a reproductive catalyst.

The formation of crystals of alum under certain conditions is such that "a host of descendants may grow and reproduce in the nutrient solution." X-ray photographs show that these alum crystals retain their specific "space-lattice" structure throughout the substitution of many materials in the solution, "the points in the lattice being taken by any materials whose outwardly directed fields of force are flexible enough to adapt themselves to the particular set that is in the local ether." Alum crystals afford, then, an analogy with the processes of metabolism and reproduction which go on in living cells. A peculiar and remarkable charac-

teristic of living cells is the utilization only of the dextro-rotatory crystals of any racemic substance. The sugars used, for example, appear dextro-rotatory when examined by means of a polariscope.

The most important part of a living cell is the nucleus. Now in the reproductive cycle of the cell each chromosome of the nucleus doubles its mass and divides into two equal parts and each part enters one of the two daughter cells. To explain the transmission of inherited qualities it is supposed that each chromosome is formed of a very large number of genes, each of the size of small molecular groups, and that the addition, removal or modification of the genes produces changes in the ovum and the organism which develops from it.

It has been suggested that a virus and a bacteriophage are formed of free living units of the order of a gene, and that such units were first to appear in the primeval evolution of life, but viruses and bacteriophages do not grow apart from living cells. "Viruses," says Boycott, "are almost wholly alive; the growth promoting substances from injured tissues almost wholly dead; the bacteriophage indeterminate;" this is an invisible filtrable agent which lives like a parasite on bacteria and causes their dissolution; it can survive for a long time apart from bacteria, but multiplies only when bacteria multiply,

and proportionately. It is claimed that a suspension of bacteriophage can be obtained which at a dilution of one in ten thousand million million contains no demonstrable proteins, but is active and multiplies in presence of bacteria.

In the case of Plymouth Rock chickens, starting with normal tissues which are then artificially irritated, a tumour can be produced. The extract of such a tumour can be filtered runde pressure through porcelain, and a very little of this filtrate put into another chicken may provoke the growth of a large tumour, and so on. Multiplication of the cause of the tumour, virus or whatever it may be, is then clear. In the case of distemper, foot and mouth disease, yellow fever, etc., which are spread by a virus, the infecting agent multiplies in and spreads from one animal to another. Cancer, on the other hand, can start from normal tissues provoked by artificial irritation. Whether the irritation leads to a virus infection from outside which produces cancer, or the growth-promoting substance is produced from the irritated cells themselves, no one can as yet say.

The primeval units of life, however formed, were maintained and stimulated to spread and mutate by the play of radiant energy. Fission resulted from instability of the living substance and fusion occurred through interplay of forces of attraction and repulsion. This led to

greater vigour, new mutations, and fresh adaptations to the environment. The male element was evolved perhaps for invigorating and starting the development of the female egg at times when the environment was suitable. Reproduction is immensely rapid when destruction is great, e.g. the microbe, but very slow when the life of the individual is stable, e.g. the elephant. As death is postponed by hygienic measures so reproduction decreases (Boycott).

It has been suggested that the genes of the chromosomes of the nucleus by acting as catalysts direct chemical changes which result in growth and other functions of the living cell. Pushing the mystery back to the gene does not help. A claim has been made that there is a sex-determining chromosome and that this is present in the male element—the spermatozoon in the case of man. There are, however, protozoa which have exactly the same number of chromosomes whether developing into male or female zygotes or remaining asexual (Dobell). It has been claimed that mutations are made in the fruit fly (Drosophila) by their exposure to X-rays, and that as the electrons are as apt to hit one gene as another the mutations produced by X-rays are as random as natural ones. They include both inconspicuous and conspicuous changes; the more easily overlooked ones are naturally the more frequent. The obvious

mutations are said to breed true to their new type, and new variants result, which crossed with other forms obey the same laws of Mendelian inheritance as variants naturally arising. It is objected to these claims that the variants produced by X-rays, may, however, not be mutations but monsters such as are produced by injury of embryos.

The bringing together of dissimilar germinal substance produces the extra size and vigour which is shown by hybrids, and hybridization is of major consequence in producing new varieties; thus, 3,000 named varieties of dahlias have been raised from a few elementary strains and a few possibly natural mutants. Millions of the new varieties which arise are less well organized for the struggle for existence; only a few are well adjusted and survive. Eugenists maintain that much can be done to improve mankind by careful selection of mates, and prevention of breeding of the "unfit," but success of hybridization experiments generally cannot be prognosticated and the expected gains from crossing are most often not secured. The uncalculating methods of a Burbank come off when calculated ones fail. In human society, too, upbringing can make useful citizens of all except the complete idiot. Highbrows are not suitable for menial tasks. For evolution of living organisms two conditions

appear to be required, mutations infinite in number but which need include only a minute proportion of good ones and the power of multiplication which, continued over a great lapse of time, by something akin to a geometrical progression becomes prodigious. The rôle of "natural selection" is to eliminate or restrict the number of "unfit," and so make room for the multiplication of the others at the rate required to allow the combination of good mutations to appear. Sexual reproduction greatly promotes the formation of new combinations. "If Man," says J. Muller, "can produce mutations as shown by the motley shapes of fruit flies produced (by X-rays) in the laboratory, he will soon apply this to domestic animals and plants, and in time, perhaps, to himself, and not be content to remain the catspaw of natural forces to be fashioned, played with, and cast aside." The stability of existing species shows, however, the conservative principle while the variability of individuals manifests the creative power of nature. The action of the environment keeps the species stable. Thirty-five breeding mice were irradiated in various doses by Dobrovolskaia Zavadskaia and 3,000 descendants studied. Two mutations only were noticeable, a waltzing mouse and a short-tailed one, and these had already been observed in the stock from which the breeders were

taken. The expectations of J. Muller do not, then, seem likely to be fulfilled.

It is noteworthy and significant that fertilization of ova can be brought about artificially, e.g. by changing the concentration of salts in sea water, or by pricking the egg. Through this last method a tadpole developed and survived to the frog stage. A feminist writer has looked forward to the perfection of such immaculate conception and the elimination of the male!

There are certain species which produce females parthogenetically while males are called forth by exposure to cold and other agents which reduce metabolism and activity.

It is noteworthy that the interplay of molecular forces, under certain conditions, produces structures outwardly resembling living cells. Thus, drops of oil may break up, grow in size, and drops of Indian ink and salt solution by diffusing into each other form shapes like those appearing in cells before division; shapes resembling those of cells arise when drops of potassium ferrocyanide spread over plates of gelatine (Leduc). The power of living cells to concentrate ions can be imitated by collodion membranes permeable to small molecules but not to small ions. If a substance passing through the membrane in the form of molecules is converted into ions by chemical reaction with some

other non-diffusing substance it will concentrate inside the collodion cell in ionic form.

Just as microbes can be cultivated on media, so, too, living cells taken from the body can be cultivated in glass vessels on suitable media and under suitable conditions of temperature and atmosphere indefinitely. The cells grow and multiply and by frequent implants on to fresh culture medium the propagation of life seems eternal. On culturing white blood cells the various varieties disappear and there persists a simple type of cell which develops fibroplastic powers. So, too, with the heart cells of the embryo chick taken many years ago by Carrell; fibroblasts have been cultivated therefrom ever since, and vestal virgins, so to speak, in his laboratory attend an eternal fire of life. Growth of the cells may be stimulated by extracts of injured cells. The growth-promoting substance is certainly not alive and probably is a relatively simple chemical substance.

A culture of cells has been slowly cinematographed and a whirl of activity within a dividing cell made evident by quick motion of the film.

It is very noteworthy that heart muscle cells when cultured show a variety of reaction in response to the environment. They may stretch out and fuse to form an inactive sheet, or separate on the surface of the medium, grow and divide actively, and resemble sarcoma cells,

or migrate and become rhythmically contractile. The change from the early embryonic type of cell, each capable of developing the body, to the specific functioning adult types are due to common general changes in the organization as a whole, and external influences limiting growth and polarizing the cells.

The solvent power of water, and the buffer action of bicarbonates present in all natural waters, are two important biological factors. The combined properties of hydrogen, carbon and oxygen thereby introduced into organisms, make possible great varieties of chemical combinations and reactions, freely allow transformations of energy, and maintain stable organizations. The stability of unicellular organisms is afforded by sea or fresh water, of the cells of higher animals by an integument and an internal medium, the blood. Every cell of the body has at its disposal the resources of all the other cells which by maintaining the normal constitution of the blood check and reverse variations from the normal. The integrative action of the blood is then of first importance.

Looking back to the simplest units of life evolved in sea water under conditions which no longer pertain in the world, we can conceive of this life substance persisting and spreading through hundreds of millions of years guided by the environment into myriads of structural

adaptations which persist so far as they help in the persistence of life. The cells of our body form a part of that continuum of living cells which in the past gave origin to the laying down of vast limestone and coal strata and now forms the lovely child, the robin redbreast, the ravening shark, the poisonous viper, the lily of the fields, the horrid parasite and the microbe of pestilence. The adaptability of the living cell is shown by the existence of salt and fresh water, and of aerobic and anaerobic organisms, of microbes in hot sulphur springs, of fish in the vast depths of the sea which withstand a pressure of some hundreds of atmospheres of water and secrete oxygen in their swim bladders at a pressure which kills all surface organisms.

The history of his evolution and the close relation of man to the primates are shown in the stages of development of the human embryo, by his vestigeal structures, by blood tests common to man and the apes, and by the skulls of primitive man.

Few realize that the subconscious life of the cells of our bodies exceeds the conscious by some million million times or more, for the unconscious living cells of the body are myriad in number. In every tiny droplet of blood, the size of a small pin-head, there are some five million red cells, in the whole blood myriads. There are myriads of cells in the organs such as

the liver, kidneys, etc., myriads living in the skin and alimentary canal, and forming the muscles. In the brain, the seat of consciousness, there are some fourteen thousand million neurons. Think of the million million atoms in each cell and the electrons and train of waves in each atom. A single living cell is as complex as a large organism, for these are made up of multitudes of cells arranged in organs, in each cell of which the life processes, while conforming with those of a single cell organism, specialize in one or other function for the good of the whole. The cells of our body die in myriads and are replaced by others in the course of life.

Immunological reactions enable us to detect blood relatives from the rest of a species so that an individual difference stamps all the cells of the body of each of us! The study of the specific reactions of immunity have shown, too, that the spatial arrangement of certain groups in the reactive part of the protein molecule determines the specificity of the entire complex, something is tacked on, as it were, which alters the combining power of the whole. There is evidence that anti-bodies are produced by chemical adjustment of injected antigen to tissue colloid, the resulting products being semi-permanently incorporated in the living tissues and body fluids.

In living cells processes of synthesis and

decomposition are regulated by a continuous interplay of all kinds of atoms and complexes of atoms: there is a multiplicity of reciprocal reactions between all the products of intermediary stages of metabolism. The nucleus of a cell controls growth and assimilation of food; separated from its nucleus a cell dies. Each successive step in the building up or breaking down of all tissue components of the body, even of individual fractions of individual proteins and sugars; is the work of special "active" molecules or catalysts produced by cellular activity in various organs; if any step in the process fail the intermediate product in being at the moment of arrest will escape further change, "just as when the film of a cinema is brought to a standstill the moving figures are left feet in air." There are certain rare inborn errors of metabolism such as albinism, alkaptonuria, cystinuria, pentosuria, porphyrinuria. The last makes the individual fatally sensitive to light. Such errors may be inherited; thus hæmophilia, or tendency to bleeding, has been traced back in one family for twelve generations over a period of 250 years, affecting 610 individuals. The males suffer and females transmit the error.

At the very start of a developing embryo the arrangement of the materials of an ovum into the primary axis of the embryo is determined by the track of the spermatozoon as it pene-

trates to fuse with the nucleus of the ovum and form the zygote. The nuclei of the cells formed by the division of the zygote at first seem equivalent, so that when separated each possesses the power to produce the whole embryo. The subordination of one cell to another and co-ordination of the whole are brought about by interplay of forces of infinite complexity in the materials of the ovum and the spermatozoa. Because we cannot follow or understand these forces there is no need to have recourse, as a savage does, to belief in demons or in a vital spirit, or entelechy of Driesch. There is neither more nor less need to invoke an indwelling spirit which directs the growth of an embryo towards a predestined end, than there is in the case of the atoms of a crystal. The power behind the electron suffices for the evolution of an infinite universe, and life on the earth. "The behaviour of an atom is just as mysterious as the behaviour of a wasp," says Boycott. The environment influences the development of the embryo from the start. Thus, if the line of division of the frog's ovum into two cells follows the track of the spermatozoon on its way to form the zygote, and the two cells are separated, each gives rise to half an embryo. But when the plane of division of the ovum into the first two cells is oblique to this axis, each cell tends to

grow into a complete embryo. Monsters can be easily produced by experiment. Thus, if the embryo of a newt in the gastrula stage be constricted in the middle by a silk thread, a larva with two heads is produced; similarly, if the two-cell stage of a frog's egg be enclosed between two glass plates and then is kept inverted in clear water for a few days, there results a larva with either two heads or two tails.

Attention has already been drawn to the fact that cell influences cell by chemical messengers, active particles circulating in the blood, so that all are balanced in growth to serve a common end.

Thus, as Boycott points out, blood transfused into a normal animal is got rid of, but blood transfused to make good a hæmorrhage is not got rid of, it takes the place of the process of regeneration of blood which otherwise occurs. If one ureter is tied, the corresponding kidney atrophies, while the other kidney hypertrophies; if the tied ureter be opened and put to drain, e.g. into a gut, the atrophy continues, given that the hypertrophy of the other kidney is already accomplished, otherwise atrophy is replaced by restoration of the kidney. A shrimp (alpheus) has, on one side, a big crushing claw, and a small cutting claw on the other side. If both claws are cut off, each regenerates of its own kind. Cut off only the big one and a small

claw comes in its place, while a big claw grows on the other side so soon as the moult takes place. Take this off and the reverse set of changes occurs.

One kind of newt has a brown egg and another a white one. Spermann grew both kinds of egg side by side till the developing embryos reached the early gastrula stage. Then with a needle he transferred the upper lip of the blastopore from the white to the flank of the brown embryo. The cells of the brown embryo surrounding the implant in place of normally forming a flank and belly were now impelled by the implant to form a spinal cord and a brain, and this in spite of the fact that the brown embryo was already growing a spinal cord in the normal position.

Lewis, operating on a very young tadpole, in which the developing retina of the eye appeared as a bulge on the side of the fore-brain, cut this off and pushed it back under the skin as far as the fore limb. Sealed with some egg white the skin wound soon healed and the tadpole grew. The retina developing in its new place compelled the skin there to form a lens.

Harrison removed from a young newt the fore-limb bud and grafted this far back in the flank of another embryo. The bud grew into a limb in the abnormal position and a nerve developing from the spinal cord grew into this

limb and supplied it, although normally this nerve would not have supplied a limb at all.

The male Lepidosirin, a lung-breathing fish, at each breeding season produces red vascular filaments on its hind limbs, which, hanging in a hole in the bank where the eggs are hatching, afford a supply of oxygen to the Lepidosirin larvæ. A chemical messenger from the larvæ produced by the want of oxygen is the probable excitant of these remarkable outgrowths.

It is claimed that cells can influence the growth of neighbouring cells by emission of rays which pass through quartz and not through glass (Gurwitsch), for example the number of mitoses in the meriostem of an onion root may be increased by the near presence of a growing tip.

If the growing tip of a seedling plant be brought near to the stump of a rootlet severed from the plant and placed horizontally in water, it causes the tip of the rootlet to grow downwards. Such influence may be effected not by rays but by growth principles acting unequally on the upper and lower cells of the rootlet.

There are, then, vast new fields of biological observation just opening and the revolutionary theories of physics have as yet been scarcely applied in the field of chemistry, or in biology.

While the myriad cells of the body by chemical messengers through the medium of the blood share in preserving the life of the whole,

the evolution of a central nervous system makes possible quick responses to the environment for maintaining posture, securing food, escaping injury, and promoting sexual propagation. It is motile organisms, not sedentary protected ones, which require a nervous system. The fundamental phenomena of sensation, response and memory are observable in a unicellular animal such as an amœba, which shows aversion to strong stimuli whether of contact, heat, light, electricity, or change of salinity of the water in which it lives. While its actions are mainly directed towards capture of food, through experience it may cease to take in useless granules and select others, a first evidence of memory. Ingestion is determined not only by the outward environment, but by the inner and changing state of the animal.

A sessile infusorium (Stentor) when repeatedly stimulated by a jet of water at first turns away, next retracts into its tube, finally quits this shelter and going off to a new place secretes a new tube. Such action betokens a rudimentary mental process.

A paramœcium placed in a small capillary tube, full of water and closed at either end, swims to the end and then makes many attempts to advance to left or right, finally after 30 to 50 fruitless efforts it turns itself through 90° with the same sort of difficulty as a car is turned

in a narrow road, then swims to the other end to repeat the performance. The number of vain efforts become, however, fewer, and finally the infusorium learns to turn very quickly. Different infusoria, just like children, vary much in behaviour under such difficult conditions and the same infusorium may respond differently on different occasions, its reactions depending on its physiological state and on the external stimuli, neither of which are ever twice the same. Every instant is creative of a new state in such a living organism, no less so in every atom of the universe.

There are myriads of white cells in the blood, eating, digesting, feeling, moving as amœbæ do, and myriads of ciliated cells lining the breathing-tubes from end to end and by their ordered motion sweeping clean the airways. The ciliated cells of the windpipe continue their cleansing work after this tube has been removed from the body, and kept for some days in a cold chamber and then placed in water at body heat. The cilia are co-ordinated by a sluggish type of transmission of excitation which spreads along the epithelium like that seen in sponges which have a simple type of muscle and no nerve.

A jelly-fish possesses in its rhythmically contracting umbrella sensitive marginal organs, a nerve net not so sensitive, and muscle least sensitive of all to excitation. There is no con-

trolling nerve centre in sea anemones and their motor reactions are determined both by the stimulations received from the outer environment and by the inner physiological state, e.g. whether food has recently been absorbed. The nerve net and the motor reactions of a man's intestine are similar to those of the anemone.

In the nervous system of higher animals nerve impulses travel in one direction only from the sensory receptors to the motor effectors over circumscribed pathways with interposition of synapses consisting of terminal branches of nerves arranged to influence nerve cells, as it were, by induction. No simple reflex actions take place between receptors and effectors for the relay cells, comparable to telephone exchanges, are developed so as to produce from diverse and contradictory sensations responses adapted to the welfare of the whole body.

The responses of the higher animals are diverse and variable in consequence of the delicacy of the internal equilibrium which is maintained by millions of receptor and effector cells and millions of "middle men" or relay cells interposed between these.

It is the skin, be it noted, along the middle of the back in the very early stage of development of the embryo which folds in to form the nervous system; the cells folded in first becoming effectors connected with muscles; those last

folded in become receptors connected with sense cells. The sedentary primitive type of animal developed radial symmetry equally exposed as it was to environment. The motile type moving forwards developed a head end fitted with specially sensitive organs and a brain, the stimuli of the environment in each case called forth those adaptations which preserve life. As a striking illustration of such is the following: The males of the deep-sea oceanic angler-fish as soon as hatched and when still numerous seek the females, and if one finds a female it hangs on by its mouth; then its lips and tongue unite with the skin of the female and the male becomes a degenerate, dwarfed parasite retained for its power of fertilization. This parasitism is attributed to the difficulty there would be in the male finding the female in the dark abyss of the ocean.

It is very noteworthy that one or other part of the brain develops in accordance with the method of securing food. Fish which smell their prey have well-developed olfactory lobes; fish which see their prey have large optic lobes; those with barbels which taste it in the mud a corresponding development of lobes on either side of the hind brain which belong to the facial nerves (Muir Evans).

While a dinosaur, big as three elephants, feeding on swamp vegetation, had a brain the

size of one's thumb, in the number of neurons and complexity of pathways, the nervous system of man, who has to live by skill, far exceeds that of the stations and wires of the whole telephonic and telegraphic systems of the world. In the cortex of the great brain there are computed to be fourteen thousand million nerve cells or neurons (A. Keith).

A century ago, any unravelling of the structure of this nervous system, now effected by simple means, must have appeared impossible. Medullated nerve fibres possess a fatty sheath, and the characteristic reaction of this to certain dyes makes it easy to follow in serial sections, the chief receptor and effector paths of the central nervous system, as these develop in the embryo at different times. Thus, the chief effector path from the cortex does not develop till the baby is born and begins to move about. Again, nerve fibres cut off by injury or disease from their neurons, degenerate and certain dyes by making the degeneration of the fatty sheath evident reveal the course of these fibres in serial sections. The nerve cells, or neurons, with their axons, or nerve fibres, and dendrons interlacing like the branches and twigs of a tree make up the grey matter and can be made plain in microscopical sections by special selective methods of staining. Granule or stellate cells in the cortex cerebri have been compared to

the jack plugs of a switchboard; while their dendrites form synapses with the collaterals of distant neurons, their axons break up at once and form synapses with the dendrites of the next neurons in order. They afford the means whereby the multiplication of neural pathways is utilized. Extensive disease of these cells leads to dementia, if pre-natal to amentia.

A nerve impulse is accompanied by an electric change in the fibre in which it travels, lasting at any one spot approximately a thousandth of a second and of the intensity of a few millivolts. With the aid of wireless amplifying valves the electric change in a single nerve fibre coming from a single nerve ending has been recorded by Adrian. The fibre transmits a message on the principle of "all or none" by a series of waves. Whatever be the stimulus that produces sensation, pressure, heat, light, etc., greater intensity is registered by greater wave frequency. So, too, with muscular contractions, while variation of the number of muscle fibres involved is a coarse adjustment, the fine adjustment is by variation of frequency of excitation. If a pair of fine needle electrodes are thrust into the biceps and the action currents led off to a system of amplifying valves fitted with a loud speaker, then with varying force of contraction the pitch of the sound may be heard to wax and wane.

Some few score years ago the first attempt at measurement of the rate at which the nerve impulse travels was regarded almost as an impious act; it proved to be relatively slow, viz. about a hundred feet a second. The nature of the impulse remains undetermined, but it seems established that it is a progressive reaction depending on liberation of energy by the fibre itself, and that the form of energy concerned is electrical. In mammalian nerve fibre the frequency of an unbroken series of impulses may be as high as 200–400 a second. The process of recovery between each stimulus may take, then, less than five thousandths of a second.

In the surface layer of a quiescent fibre the molecules are conceived of as arranged with their electrical charges in equilibrium, the surface being polarized and impermeable to certain ions; the stimulating current depolarizes the surface at the cathode with the result that this region becomes "active," and the activity causes a movement of ions which has the result of depolarizing the surface farther on. This, in turn, becomes active and leads to a further spread of depolarization and so the active region travels down the fibre accompanied by the electric charges which give rise to the action current.

The outgoing ions are supposed to be re-

plenished by the breaking down of larger into smaller molecules; fatigue may be due to depletion of the store of active material. Action currents can be excited in iron wires immersed in nitric acid. Rhythmical electrical variations, 120 a minute, also take place in passive iron wires immersed in 80 per cent. solution of nitric acid, at lower concentrations the rhythm falls. The process of activation of the surface film of the wire is very rapid in every case, but the process of becoming passive again is slower in weaker concentrations. An analogy of this rhythm with that of the heart has been drawn (Lillie).

The discharge on stimulation of a single sense organ such as a muscle spindle, or a Pacinian corpuscle, has been investigated by Adrian. With a steady stimulus the impulses are evenly spaced and the only variable is their frequency which gives a measure of the intensity of the excitation in the sense organ. A frequency of 200—300 a second has been recorded from a single muscle receptor of the frog, the discharge being brought about by a rapid extension of the muscle.

As a million or more sensory fibres enter the spinal cord in man, it is evident that, apart from the special senses and the brain, the range of possible body sensations is very large.

Sensory fibres, according to their diameter,

differ widely in conduction rate and in the intensity and rate of rise of the action current. It is conceivable, then, that characteristic time relations of impulses in different fibres determine specific effects, granting the existence of relay receptors in the central nervous system which are tuned to respond preferentially to impulses of a particular form. We know that different types of sense organs are supplied by nerve fibres of different size and that fibres from receptors of different type arborize widely over a number of nerve cells; the path taken by a particular message may then be decided by the characteristic form of the impulses.

A nerve after stimulation is refractory to a second stimulus for a very short time. In sense organs the refractory state may last longer. We are temporarily deafened by a loud noise and blinded by a glare. After gazing on a red light we see on shutting the eyes at first a red and then a green image of the light. Excitations persist, then, in their effect, just as some substances not only fluoresce while irradiated with invisible ultra-violet rays, but phosphoresce long afterwards. In the millions of neurons of the brain persistence of sensory impulses has been evolved so that memories result. The memories are revived by present impulses which are, it is supposed, in tune with the persistent ones. By strong excitation and repetition of

similar excitations memories become more and more fixed and pathways beaten out for effecting specific motor reactions; thus conditioned reflexes and habits are formed. Through present sensations arousing memories of past experiences we are able to visualize possible future experiences, and so form expectations and arrange conduct. Experiences relevant to furthering, or hindering, social success are especially retained as memories, and it is by observing the conduct and success or failure of others that we learn to avoid evil and seek the common good.

Sensory stimuli to be effectual in provoking motor reaction must be relevant. Thus, a blind-worm is responsive to the gentle fall of rain which brings its food, the grey slug; but wholly indifferent to a motor horn or a jazz band (Wood Jones). Things relevant to the civilized man are irrelevant to the savage. The buzz of a mosquito may be a far more relevant stimulus than a clap of thunder. Relevance is largely lost to the lunatic, and never fully possessed by the feeble-minded. Certain stimuli are relevant through inheritance, reflex pathways being formed before birth necessary for preservation of life, e.g. that of flying of nestlings and sucking of babies; to excite feeding there is required not only the sensing of food, but the humoral condition of the body

which results in hunger. Without hunger the smell, taste or sight of food is irrelevant.

Child study teaches us that concomitant with the laying down of complex cortical association patterns, memory of past events and consciousness of self become evident, and that as education beats out habit pathways, inherited instincts become less significant. Education and example are paramount influences.

Consciousness generally accompanies any widely diffused sensory excitation of the cortical pathways which results in inhibition of those motor effects which would have adequately discharged the excitation.

Experiments on interchange of the attachment of muscles, e.g. of those which move the eyeball, show that sensory excitations are generally diffused through the nervous system until that pathway is found which calls forth the adequate motor response, any wrong response being reflexly inhibited through impulses arising in the sense organs of the ineffective muscles. After such an operation the eyes continue to move together in proper fashion and follow a light.

The same thing holds good when the central end of one motor nerve is joined to the peripheral end of another, e.g. the musculo-spiral to the facial. After completion of the regenera-

tion of the nerve fibres emotions are accompanied by the usual facial expressions.

While consciousness of pain arises in the brain, the seat of pain is referred to the injured region. We know that an injury is no longer felt when the sensory nerve coming from the injured part is anæsthetized, and that pain is referred to a limb long after this has been amputated; the stimuli arising from nerves in the stump are referred in the brain to the periphery in accordance with habit established during life.

After division of a cutaneous sensory nerve sensibility to pain, touch, light, pressure and temperature disappear in the area of skin supplied by the nerve, but the sense of position and passive movement, and of deep pressure and vibration persist, for these are dependent on the sensory nerves of muscles, tendons and joints. Regeneration of the cut nerves slowly takes place and as the nerve endings regenerate appreciation of pain comes back first, then extremes of cold and heat are felt, with poor localization, notable irradiation and over-effect; next there return sensations of light, touch and pressure and of intermediate range of temperature. Ability to discriminate between two neighbouring points is most tardy to return. How altered, then, are conscious sensations through division of sensory nerves! What a

profound effect, too, has blindness and deafness on a child! The deaf child is dumb unless taught by lip speech.

The quality of a sensation depends upon the path travelled by the nervous excitation, e.g. that from retina to occipital cortex gives vision, that from the cochlea to the temporal cortex hearing, and so on. Excite the optic pathway electrically or mechanically and only a sensation of light results. Somehow in the brain as a whole there results a process of integration of nervous messages which provoke rise and decline of conscious sensations corresponding to the rise and decline in the excitatory processes in the receptors. We do not know how a pattern provoked by nervous impulses in millions of neurons each with myriads of atoms causes thought; no more do we know how the environment causes hydrogen and oxygen atoms to combine and form water. We can arrange the play-house and observe the results, but the power behind all action is hidden.

The past century has seen the question of localization of function in the higher parts of the nervous system, which was put forward by Gall (1810) and denied by Fleureus (1824) on account of experiments performed by him on birds, reintroduced by Hitzig and Broca (1860) and greatly extended in detail by Ferrier and

others, and now finally rejected as far as the cerebral cortex is concerned. Every concept involves the whole of the nervous system in so far as reference to unconscious memory habits; but not every stimulus causes every neuron to be active. Complicated conditioned reflexes occur in complicated pathways, the number of the unconscious being to the conscious as many million to one. All actions are guided by the previous conditioning of reflexes acting in a nervous system which is characterized by inherited nervous qualities of response. When orderly conduction along the millions of paths which constitute normal reason is disturbed by toxæmia or exhaustion of neurons through ill feeding, fatigue or microbic infection, disordered mind results.

Movements can be provoked by electrical stimulation of the ascending frontal gyrus, the so-called motor centre of the cortex of the brain, when this is exposed by a wound, but these movements have neither the complex pattern, nor the purposefulness of natural movements; relatively simple in kind, they appear to be provoked by stimulation of pathways passing through the cortex and not of functional centres in the cortex. The patients experience a sensation of forced movement of the limb, just as when a peripheral nerve is stimulated. Similarly, stimulation of the post-central gyrus, in which

tactile sensations have been localized, produce sensations of tingling similar to those produced by faradization of a sensory nerve. In a case in which the outer surface of the occipital lobe was stimulated, crude sensations of light were experienced; crude visual hallucinations are connected with lesions of this part.

Experience shows that it does not matter to which area of the motor cortex nor to which cerebral hemisphere a surgeon transfers a field of peripheral innervation, e.g. by connecting one nerve with another. Complete recovery of motion, co-ordination and sensibility result, provided the path in, and the path out, are fully restored—the path is the important thing, not the cortical region. Thus the middle cord of each brachial plexus of a dog was divided so that the proximal end of one could be passed under the trachea and united to the peripheral end of the other. The dog on recovery walked, ran and held down a bone quite naturally. Now the cortical area for extension of the right fore limb had been switched over, as the result of this operation, from the left to right. Stimulation of the right cortical area now produced movements in both limbs, viz. extension of the left paw and flexion of the left elbow and contraction of the right triceps and extension of the right paw. For such recovery of function the afferent paths are all important, for effective

movement is secured only by unconscious sensations streaming in from muscles, joints, etc. Consciousness of movement only comes via the afferent nerves. Patterns excited by these nerves when an ineffective movement is made guide the central nervous system to complete functional restitution. A running analysis from what is called the proprioceptive system accompanies every movement and, in addition, analyses from the auditory and visual sense organs so far as these are essential to the function. Hence movements and sensibility are not separately represented in the cortex. In the case of the visual region of the cortex reception of the visual pathways are arranged in regular order. Destruction interferes with vision merely in proportion as it cuts these pathways. Disorientation results from severing on either side the trans-cortical path running forward from the occipital lobes. After such injury, e.g. from a bullet, a man could see, name and count every object but could neither avoid running into large objects, or find and pick up small objects. In cases of extensive cortical destruction of the occipital lobe so long as the region of the calcarine fissure is left intact to which goes the path from the central spot of the retina, acute central vision persists; impairment is then only of the peripheral field of vision and of small account.

The faculty of hearing is greatly disturbed in man by a bilateral lesion of a small cortical area in the temporal region just where the central auditory path enters. Undercutting the white matter beneath this area by severing the path has the same effect. Faculty of speech depends upon the analysis of correct articulation received from the ears and proprioceptors of the articulatory mechanism, and faculty of writing on a similar analysis received from the eyes and proprioceptors of the hands. Jargon results when the respective afferent cortical pathways are severed. Speech is lost in the order of the depths of impression, foreign speech going first, voluntary next, comprehension of the spoken word last. The left cerebral hemisphere is particularly engaged in speech as it is with the movements of the right hand. Provided sufficient healthy cortex is available and neuroblastic development is still active, as it is in the young, paths which subserve functions late in development allow redevelopment of functions disordered by cortical destruction.

Commencing in the periphery and entering the central nervous system each receptor pathway converges with other paths, which modify its function at each convergence; spreading widely in the cortex with multitudinous possible convergences and modifications of function, it gathers again to return as an effector pathway

to the periphery. So long as compact and single it is vulnerable, but where diffuse it is not so.

That the brain functions as a whole is shown by the great power of compensation for widespread destruction of the cortex, and by the fact that more pronounced effects follow severance of the white matter, that is, of interconnecting nerve fibres, than of the grey cortex. The so-called "motor" region of the cortex localized in the post-central gyrus can be destroyed on both sides in a chimpanzee, and within a few days the animal learns to open a food cupboard with a key and with his back to the door so as to conceal his action so that this is unguided by sight. The ablation of that part of the cortex which on excitation provokes facial movements never produces the least transient paralysis of face, jaw, tongue or larynx in anthropoids. Horsley removed the arm-excitable cortical area of a boy on the right side, and the boy recovered sufficiently to play tennis. Serious speech effects result more from severance of subcortical connections than from destruction of the cortex.

Word blindness and deafness and aphasia are caused by severance of pathways of afferent and efferent nerves, not by destruction of cortical centres.

Mental processes are, then, a function of the

nervous system as a whole; of all cerebral lesions, those of the corpus callosum, which joins one hemisphere to the other, produce most reduction of mental function.

An after effect of brain injuries, and particularly gunshot ones, is a change in the whole personality. The patients can only act in a living situation, and are unable to function if asked to account for their actions and to differentiate between themselves and their entourage, with resulting moral defect. If unable to carry out a command the patient becomes mentally disordered. His mind must be kept occupied with activities within his range of performance, and then all is well.

Integration in the cortex cerebri of the sensations arising from the receptors, in relation to the whole environment, external and internal, has led to the triumph of man. In him the hand set free by the assumption of the erect position could be used for grasping, feeling and tool-using. In co-ordination with the eyes the hand afforded a wide knowledge of the environment and of the body itself. By the hand carrying food to the mouth the muzzle could be shortened and the eyes brought to the front, giving binocular and stereoscopic vision. The hands holding objects near and steady made possible fixation and binocular vision of objects. "The larynx, tongue and lips learnt the business

of speech so that behaviour became implicit as well as overt; and when the hand and eye by invention of writing and reading purveyed thought as well, the last step forward in man's evolution was taken (Wood Jones).

Thus, the Pekin, Piltdown and Java men, with marked simian characters of skull, evolved from the primitive anthropoid type, and finally civilized man appeared. Be it noted that the thalamus and corpus striatum, the great nuclei of grey matter at the base of the brain, carry out innate and instinctive movements in lower mammals, most of which in man are controlled by the cortex cerebri. In man the higher senses and the cortex take over far more complete control of all actions.

The researches of Sherrington and Magnus have very greatly advanced our understanding of the reflex working of the central nervous system. We know that bodily actions are co-ordinated and effected without consciousness. While consciousness acts as accelerator and brake, the bodily engines carry out actions controlled in the central nervous system by a ceaseless stream of afferent impulses from muscles, tendons, joints, otolith organs, etc., of which we have knowledge only by laborious research, unconscious impulses which excite these and those muscles, and inhibit these and those others.

One third of a motor nerve is made up of afferent fibres, and afferent impulses from these add to the central excitation, producing inhibition of inadequate motor effects until the adequate response results. With every sensation muscles are made tense and ready for action and afferent impulses from these muscles add to and regulate the central excitation. The sense organs responsible for postural adjustments have to keep the central nervous system constantly informed of the relations of the different parts of the body and to do this their messages must not only be constantly maintained, but accurately graded, hence the evolution of nerve fibres insulated by a layer of fat and of encapsulated nerve endings. Examination of the muscle spindles and nerve endings in tendons and joints helps us to recognize how thousands of impulses accompany every position and movement—and all these are subconscious.

While the cortex controls the initiation of movement, having power to integrate sensations of the present with past experiences or action patterns, and inhibit reflex action, antagonistic, synergic and fixator muscular movements are all controlled subconsciously by sub-cortical parts. Thus, muscles paralysed so far as concerns voluntary movements by injury to the cortex may be used in low level operations, e.g. raising of the arms in yawning. The stimuli

from sense organs in muscles, joints and deep tissues, which are subconsciously co-ordinated for maintaining poise and balance, appear to be particularly dependent on the pathways of the cerebellum. In the case of the eye, the muscles regulating the size of the pupil and accommodation for near and far vision and those which turn the eyes and head in harmony are all controlled reflexly and subconsciously. Every position of the head in space has a corresponding position of the eyes, and every position of the head relative to the trunk produces a corresponding position of the eyes in the orbit. The sense organs in the labyrinth of the ear affected by gravitational pressure link up with eye movements and proprioceptive impulses from the neck muscles. The paths concerned in the control of eye movements and body equilibrium are complex and many are still obscure. When proper functioning is disturbed, as in seasickness, vertigo, nystagmus and nausea result.

There are two kinds of receptors, those that excite and those that inhibit contraction, by means of which the muscles themselves share in their co-ordination. They are not only motor machines, but possess sense organs stimulated by tension of the fibres; thus have we perception of active and passive postures and movements.

"Trains of impulses are the sole reactions

which enter and leave the central nervous system. States of excitation which can sum together, and states of inhibition which can sum together, and states which represent the algebraical sum of these two, are among the central reactions. The motor neurone lies at a focus of interplay of these reactions and its motor unit gives their net upshot always expressed in terms of motor impulses and contraction" (Sherrington).

The states and reactions of the neurons are, as compared with the processes of conduction of nerve impulses, relatively very sensitive to physiological conditions, and are delicately responsive to fatigue, blood supply, drugs, etc. Far from behaving merely as passive recipients and transmitters of impulses, the neurons modify as well as transmit what they receive. They can develop rhythm of their own, and their rate of discharge can rise and fall with intensity of central excitation and inhibition, respectively.

In the central nervous system the synapses of different afferent nerves with motor units overlap; the overlap is extremely great, both in kind and degree. Experiments on reflex actions confirm that wealth of convergence of afferent nerves upon motor neurons which is shown by the microscopical evidence of interlacing dendrites. These afford co-ordinating points where the trains of impulses interact and

are switched over into effect. When afferent impulses arrive of submaximal intensity summation of effect may be produced, but when the impulses are maximal no summation is possible because the effector mechanism is already in full action. The contraction effect of one afferent may then default altogether because the final common path is already fully occupied. Another result is inhibition due to one set of afferent impulses antagonizing another. Experiment shows that inhibition is graded both by the number of neurons excited and rate of excitation in the neuron itself. The "stretch" leg reflex, studied by recording the movements of the patella in man, is in every respect the same as that in animals, and undergoes the same sort of modification through lesions of the higher parts of the central nervous system through injury or disease as those produced by experiment in animals.

A moth burns itself in a candle through reflex movements which are made inevitable through the unequal illumination of its eyes. Using photo-electric cells of selenium as artificial eyes an electrical machine has been constructed which behaves as the moth does. A dog rests inert after removal of the whole cortex cerebri, but can reflexly be excited to walk, swim and even feed when its snout is put in the basin.

After the spinal cord has been severed by a wound in man stimulation of the foot, no less inevitably than in an animal, provokes complex co-ordinate movements, viz. flexion of the hip, adduction of the thigh, flexion of the knee and upturning of the foot and toes. The coitus reflex may also be excited in the male, and parturition carried out in the female, and all without consciousness.

Through the researches of Pavlov and his pupils, it has now become possible to elucidate the setting up of conditioned reflexes which result in behaviour. We know that the mouth waters on sight, smell or taste of food, or even on hearing sounds of cooking. In trained dogs placed in a quiet observation chamber, the secretion of saliva can be recorded drop by drop, and if the stimulus to secretion produced by giving food be preceded by another stimulus, be it a sound, a sight, a touch or even a pain, then after several repetitions of the experiment, this other stimulus of itself provokes secretion. There is thus set up a conditioned reflex. Similar reflexes have been studied in young children trained to lie quiet in the observation chamber with a tube in the mouth for draining off the saliva to a recording instrument, a funnel with electric trigger being set over the mouth for giving sweet stuff and an electric contact for stimulating the skin. If this other stimulus be

given after the presentation of food, it will not be effective; moreover to maintain the strength of a conditioned reflex, this must be regularly reinforced by the giving of food. It has been shown that the effect of two different stimuli may be summated, and that the specificity of the conditioned stimulus may be very great; thus, if the reflex be established so that a note of 800 vibrations per second produces secretion, one of 812 provokes none. The sensitivity of the ear of the dog to high notes can thus be explored; thus it was proved that injury to the organ of Corti in the cochlear at the junction of its middle upper third resulted in loss of tones below 300. A well-established discrimination between stimuli, e.g. two tones, is found to be weakened just when a new reflex is being established. That dogs, while very sensitive to shades of grey, are colour-blind was also proved by this method. In the case of tactile stimuli, it was shown that while discrimination of locality is very sharp, a corresponding spot on the opposite side of the body might be effective. It was proved that the dog can recognize small differences of temperature (1° C.) and the precise site and difference between a rough and a smooth contact.

After a dog had learnt to discriminate between a circle and oblong oval wider and wider ovals were used, till discrimination between oval

and circle failed; the animal then became excitable and neurotic and recovered only after a rest of some months. This experiment is very important as it illustrates the ill effect on the mind of insoluble difficulties. Auditory conditioned reflexes of elementary character could be established after removal of both temporal lobes, and visual conditioned reflexes based on *intensity* of illumination after removal of both occipital lobes, although those based on objective vision entirely disappeared. After division of the corpus callosum a dog loses power of localizing the side from which a sound comes.

Pavlov found that sleep may result from the non-reinforcement of the conditioned stimulus by the unconditioned one; or the continuous application of the conditioned stimulus for some time before applying the unconditioned one, or by reinforcement of a stimulus of a certain intensity or quality so that differentiation was required. In some dogs it takes days or weeks, in others years, for the sleepy condition to develop through non-reinforcement.

Injection of morphia causes a dog to salivate and vomit. After repeated injection the mere sight of the syringe may be enough. So the mere sight of a picture of a hayfield may, in very sensitive subjects, provoke an attack of hay fever. It is claimed that an immunological reaction can be provoked as conditioned reflex by

a stimulus which has been repeated just before injection of the specific antigen. Strychnine, caffeine and thyroid gland, if taken for some days, augment and large doses of alcohol depress conditioned reflexes. Bromides reinforce inhibitory activities. No sure evidence has been obtained of the inheritance of conditioned reflexes. Fresh-hatched wild ducklings, if visited when the mother is off the nest, show no fear, but let them once hear the mother's note of alarm and the conditioned reflex for flight is established.

Every human action is guided by an almost endless chain of previous conditioned reflexes, biological, racial, hereditary, educational; the conditioned reflexes of savage and uneducated men are guided less by recent knowledge and more by superstition.

Learning is built up by the addition of very small amounts day by day, by individual experiences and the experiences of others handed down through thousands of years by oral tradition, and by books. The genius has inborn acute visual, or auditory sensibility, the artist of form and colour, the musician of tone, the mathematician of spatial relations, and an unusual power of integration, but his work is done piecemeal and slowly by trial and error. Thus the artist educates himself until his hand and eye can work with the precision of

established subconscious reflexes. Integration of ideas gives excellence to his technique.

In the accord between behaviour and the environment the external characters of the body and clothing come into play. Just as the octopus changes its colour to the rock it settles on, so does the financier harmonize his appearance and behaviour with his environment, and the girl with her good looks (Wood Jones).

Through education people conform to pattern, a man is called honest because his behaviour conforms to a pattern. To how few patterns do the announcers and artists of the B.B.C. conform? The unforming originality of a genius is very rare, excites dislike, and is often unrecognized until after death.

"Memory is not a faculty of storing souvenirs in a drawer, but a piling up of past on the past which pursues itself without pause" (Bergson). The pattern of the brain is ever being created anew, varied by the new sensations acting on the old pattern.

"H. G. Wells of to-day is not the ill and angry young man of 20 who lived in 1886, struggling in the world under a heavy handicap, nor is he the H. G. Wells of 1896, represented in a photograph with side whiskers and a cascade moustache who rode about the countryside on a bicycle. The greater part of him is dead, past and forgotten."

All the fear, all the feeling, all the details of babyhood and childhood go out of conscious existence, and yet patterns laid down in the neurons in childhood subconsciously continue to influence behaviour.

Fear is the native reaction in very young children to loud noise or loss of support, rage is provoked by hampering bodily movement, love by gentle stroking, rocking and the like. Any of these emotions can be associately attached to other stimuli (conditioned). Thus, a harmless animal, and by extension, all furry, woolly things, may become an object of fear if presented with a loud noise, and persons or things hated if experienced together with bodily restriction (Watson). Experiment shows how such conditioning can be undone and reconditioning used for building up morally and socially desirable behaviour.

Psycho-therapy acts by altering such settings or patterns of the nervous system. Freud's view, as expressed humorously by Joad, is that there is a ground-floor family (conscious) small, select and respectable, and a basement family (subconscious) large, primitive, untidy, disreputable, noisy, selfish, a prey to unbridled desires. Conscience is a barmaid permitting indulgence of a desire for a certain time, and then saying "Time's up, gentlemen."

Researches on frog's muscle and heart have

led Burridge to novel conceptions of excitatory processes which he has extended to the nervous system. He finds the excitability of living cells to be of a dual character and supposes that it is mediated (1) by ions, which come and go instantaneously, (2) by colloidal aggregation which may be worked up quickly or gradually, and persist after removal of an excitation subsiding in its own time. Emotions may be due to the colloidal change in the neurons, while thought travelling swiftly goes with the speed of ions. Internal secretions influence the colloidal changes and balance the ionic influence of the salts in the blood. Youth, having at its disposal active ductless glands, can have excitation processes of high colloidal or emotional quality. Old age, on the other hand, with diminishing ductless gland activity, compensates the loss by addition of calcium ions which, besides giving increased intensity, adds resistance to change, hence obstinacy, and at a later stage senility. Alcohol lessens the ionic share of excitation, and with it thought and judgment, and exalts emotion by increasing the part played by colloids in the excitation process. Colloidal aggregation supplies to thought an affective tone, and the holding power of a thought depends on this. When fancy flies there is little behind it, the chief component is the ionic complex. Burridge conceives that every im-

pulse which activates a nerve cell leaves behind an altered state of colloidal aggregation, the degree of alteration depending on the number of activations and their intensity; training produces a higher level of colloidal aggregation, and as a conscious act is transformed by training into an unconscious one, there is gradual diminution in the ionic content of the excitation process mediating the act; the same nerve cells are engaged, but the process is changed. There are no higher and lower centres, but in any group of nerve cells there are two levels of activity, the one serves to conduct or frame an ordinary excitation process, the subconscious, the other frames excitation processes which have greater ionic efficiency and excite conscious activity in responding elements of the neurons. Excitation processes have composition as well as size, and composition determines behaviour.

Researches on muscle have led Burridge to the view that excitation process and response take place in different structures, e.g. in sarcoplasm and in the contractile material evoked by sarcoplasm. So, too, in the case of thought; there is activity of some material other than that in which the excitation processes preceding thought take place.

Sleep is a condition in which excitation processes are inadequate to excite conscious activity. In inhibition Burridge conceives that

colloidal aggregation is put out of action by a positive electrical charge which protects from calcium combination; ions and colloids cannot then interact and so there is no excitation. A rebound results when the positive charge is removed. There is another process termed exclusion by Burridge in which an ionic barrage is put up, sufficient to prevent colloidal aggregation from taking place. The maniacal condition is, he suggests, one of complete exclusion. In conditions such as shell shock, intense experiences have, he thinks, expelled or used up from the neurons the elements essential to conscious judgment.

Unconsciousness may be due to excitation processes of (1) too small intensity, (2) unfavourable composition, (3) too great intensity to evoke normal response in the responding neurons mediating thought. High effective tone does not go with good judging, for the two processes are always so adjusted that the more of the one, the less of the other; the temperament depends on the balance. Colloidal aggregation can be enhanced not only by excess of hormones from ductless glands, but by toxins. Thus, septic processes may increase it, and with this comes loss of judgment and memory and increase of affective tone just as with excess of alcohol. Hence the change of temperament with such a disease as phthisis.

Unreasonable people, such as the fanatic and lover, possess excitation processes with greater degrees of colloidal aggregation.

Such views are a first crude attempt to associate the processes of mind with changes in the physical and chemical state of neurons. They therefore are of interest and particularly in regard to the dual character of the excitation processes and the conception of a third element in the neurons which mediates consciousness.

It is evident that the interaction of myriads of atoms, each with their electrons and waves accompanying electrons, in each of the fourteen thousand million neurons computed to be in the great brain, suffice for the functions of mind and consciousness. There is no justification for calling into play "a spirit from the vasty deep, totism, magic, witchcraft, polytheism, vitalism, free-will, human immortality and divine retribution, heaven and hell and the devil, a crowd of spectres with which man's wayward and fearful imagination has for ages oppressed him, cumbering his progress in true knowledge and in command over the forces of nature."

"Nobody," says Spinoza, "has known as yet the frame of the body so thoroughly as to explain all its operations." The enduring result of the discussions of Locke, Berkeley, Hume and Kant was to make it clear that we

can have no absolute and no immediate knowledge of either soul or body.

"I can never," wrote Hume, "catch *myself* at any time without a perception; and never can observe anything but the perception. When my perceptions are removed for any time, as by sound sleep, so long am I insensible of myself, and may truly be said not to exist. And were my perceptions removed by death, and could I neither think, nor feel, nor see, nor love, nor hate, after the dissolution of my body I should be entirely annihilated, nor do I conceive what is further requisite to make me a perfect nonentity. If anyone, upon serious and unprejudiced reflection, thinks he has a different notion of himself, I must confess I can reason no longer with him. All I can allow him is that he may be in the right as well as I, and that we are essentially different in this particular. I may venture to affirm of the rest of mankind, that they are nothing but a bundle or collection of different perceptions which succeed each other with an inconceivable rapidity, and are in a perpetual flux and movement. Our eyes cannot turn in their sockets without varying our perceptions. . . . The mind is a kind of theatre where several perceptions successively make their appearance; pass, repass, glide away, and mingle in an infinite variety of postures and situations. There is properly no

simplicity in it at one time, nor identity in different, whatever natural proposition we may have to imagine that simplicity and identity."

The substratum of what we call matter and spirit cannot possibly be known by any possible predicates, so let us get on, then, with experimental observation, taking as our standpoint the assumption put forward by Huxley that the stream of consciousness accompanies the flow of brain processes, each detail of the stream being dependent upon some specific feature or detail of the total brain process with which it coincides, or to which it immediately succeeds in time. It depends on the condition of the neurons, not only as maintained by sensory impulses, but by the blood, and so on all the body cells which contribute to the common weal.

"The soul," says Lucretius, "is born with the body, grows and decays with the body, therefore perishes with the body," but the spirit behind the soul and all in the universe is infinite, imperishable, unknowable. It is consciousness of personal existence patterned on the brain with all its trivialities and worries which ceases on death. The impersonal basis of life comes from God and returns on death to God.

It is stated by philosophers that whatever has importance for us, and on reflection we find we must take account of, has reality for us, the rest

is unimportant, unreal. To the uneducated woman brought up in snobbish surroundings, petty society customs and values are then real; to the savage the securing of scalps of enemies, to the libertine a fresh conquest of female charms, while to the Newtons and Einsteins the highest philosophic ideas are at times most real, and at other times domestic or bodily troubles. Constraint and bondage of the expression of what we regard as real are unsatisfactory. The conditioned reflexes established in our upbringing are thwarted. Hence the cry for liberty and the importance to the philosopher of "free will." Our inherited qualities and the conditioned reflexes established by upbringing and education, are and must be continuously thwarted by the society of which we form an insignificant part.

We must have faith, says a philosopher, placed on something that is real, and not on something that we merely think is real, we must remember Cardinal Wolsey's words "Had I but served my God with half the zeal I served my King, he would not in mine age have left me naked to mine enemies." How are we to find out what is real?

We cannot separate personality from the body, for it depends on the normality and health of the body. To mortify the body and so elevate the spirit is not possible. The saint has

to be fed and sheltered in the intervals between his fasts and visions.

"One of the most general sources of error," wrote Robert Owen, "and of evil in the world is the notion that infants, children and men are agents governed by a will formed by themselves and fashioned after their own choice. . . . Man is the creature of circumstances and really is, at every moment of his existence, precisely what the circumstances in which he has been placed, combined with his natural qualities, make him. Surely if men ever become wise—if they ever acquire knowledge enough to know themselves and enjoy a happy existence, it must be from discovering that they are not subjects for praise or blame, reward or punishment, but are beings capable, by proper treatment, of receiving unlimited improvement and knowledge."

How low is the level of the stone-age man is shown by Darwin's description of the Fuegians. Stunted, naked, filthy and greasy, with long, streaming and entangled hair, their voices discordant and their gestures violent; with no religion, government or chief, but tribe fighting with tribe for the wretched means of subsistence. Sleeping like hares in forms in the inclement climate, living on shell fish and putrid bodies of whales and seals; each, if attacked, instead of retiring, endeavouring to

dash out your brains with a stone, as certainly as a tiger would tear you; their skill comparable with instinct of animals, not improving with experience. When one was given a piece of cloth it was torn into shreds and distributed; when a pistol shot was fired close by, one merely looked astonished and rubbed his head, the sensation being no more relevant than a motor-car is to a lion in the bush. And yet if that infant at the breast, which the father snatched away and dashed on to the rocks because the mother dropped a basket of eggs, had been rescued and educated it would have become a useful civilized man. We have already touched on the profound alteration of personality as the fertilized ovum develops to the new-born infant, and this to the child, the adult, the aged, and on the alteration made by ill-feeding, drugs, alcohol, insufficient oxygen, excessive fatigue, illness, and injury to the brain. The dancing dervish gains his vision through fatigue or by hasheesh, similarly the Buddhist or Christian who keeps vigils and fasts; by brain cell exhaustion is the so-called freedom from domination of the external world obtained. The symptoms in order are—impairment of finer motor adjustments, e.g. seeing double, and disorder of speech, impairment of attention, loss of inhibition, increased emotion, loosening of social habits, hallucination and delirium.

"I have had," says Gissing, "one of my savage headaches . . . memory, reason, every faculty of my intellectual part, is being whelmed in muddy oblivion. Is the soul something other than the mind? If so, I have lost all consciousness of its existence . . . my being is here, where the brain throbs and anguishes. A little more of such suffering, and I were myself no longer, the body representing me would gesticulate and rave, but I should know nothing of its motives, its fantasies. The very I, it is too plain, consists but with a certain balance of my physical elements which we call health."

Without the internal secretion of the thyroid gland a child is a cretinous idiot. Feeding with thyroid makes it into a normal being. Too much pituitary makes a child grow up a stupid giant. Tumour of the supra-renal gland causes sexual precocity, producing in a young child the maturity and appetite of a man.

By the removal of sex glands and transplanting of opposite ones, sex characters are changed. Through abnormal balance of these glands inverted sexual characters arise and instincts punishable by law, but inborn and therefore inevitable.

Physicians recognize a group of persons with a tendency to excitability, rapid heart, high blood pressure, liability to excess of sugar in the

blood and to high temperature from trivial infection, with overaction of the thyroid and adrenal glands; and another group showing slow pulse, liability to fainting, asthma, hay fever, nettle rash, constipation and low blood sugar, reacting badly to infections, and suffering from vague apprehensions. Temperament is ruled, then, by bodily reactions which may have inborn qualities.

Who can justly doubt that personality is bound up with the structure of the cortex cerebri? A decerebrate animal is an inconscient reflex automaton. It stands statuesque, tilt the head up and it sits and looks up, tilt the head down and it assumes the posture of feeding from a dish.

Take the case of the baby boy who stirred and cried only when hungry, thirsty or soiled, whose eyes appeared turned up whenever the lids were opened, who never smiled or made any response to his mother's voice. He lived for $3\frac{3}{4}$ years, breathed, swallowed, digested, excreted, kept warm; his brain was found to be a mere bag of fluid.

Take again the case of a man with superficial injury to the left parietal region of the brain in the vicinity of the supra-marginal gyrus. The wounded man had no difficulty in expressing by words his ordinary needs, but often appeared to have lost the connection between what he had

said and what he wished to say. He read aloud correctly and understood the significance of words and short sentences, if they did not contain a command. He wrote very rapidly as if he feared to lose the idea. He counted and named coins, but could not solve the simplest problem in arithmetic, and he had been an accountant. Unable to draw or to sum in any manner the relative position of objects in a familiar room, he yet could point to any object in the room with his eyes closed. He could not find his way about, or play games, as he could not foresee the consequence of his next act.

Dr. William Brown says "mind is an active, dynamic synthesizing force, creative, carrying on activities which even the greatest conceivable extension of our physiological knowledge would not enable us to infer from observing the brain. If consciousness be the sum of physical processes, truth, beauty, goodness and other abstractions have no real significance. Will, freedom, choice and other mental qualities are myths of consciousness. Life is not only determined; it determines; it is not only moulded by environment; it moulds environment. It is not the passive mark of physical forces, it is a dynamic spark let loose among undynamic things; a vital thing in contact, in conflict rather, with unvital things. Life is a clash

between the organic and the inorganic." To which one answers that the activities of life and mind are neither more nor less dynamic, a clash and conflict, and unexplainable, than those of atoms of dead matter. "The packing of all the potential properties of a species in one tiny reproductive cell, the gradual transformation of one species into others much more complex and having consciousness and memory," these mysteries of life are neither greater nor less than those of radiation quanta and electrons. The finger of God in stirring the ether endowed matter also with the potentiality of evolving mind through a particular play of environment.

"When I use my pen," says J. S. Haldane, "the light in which I see it is not merely that of an electric lamp, but of all my other experience. When I write with the pen the movements of my muscles are determined by the actual presence to me of innumerable past, present and anticipated future events in both my own individual history and that of mankind. The past events are not simply past and done with, like events interpreted physically or biologically, but they, and not their mere effects, are still present and active. . . . I am living and acting in a spiritual world for which separation, not merely in space, but also in time, has none of the meaning which it possesses for the world interpreted physically or biologically. Along the

years and across the oceans action and reaction are direct in this spiritual world. It is evident that in conscious activity we are face to face with facts that neither physical nor biological hypotheses are capable of interpreting. Yet conscious activity manifests itself in connection with the same beings that seem also to live and breathe as mere organisms, or to consist of nitrogen, hydrogen, oxygen, carbon and other atoms leading a wild and undefinable dance."

By those words of Haldane, "actual presence to me," the conscious guidance of the pen by all that innumerable past seems clearly suggested. I venture to suggest that the movements of the pen are determined by a pattern laid down in the brain with its fourteen thousand million neurons and infinite myriads of atoms and electrons and their train of waves, a pattern laid down by past experience and education acted on by present sensations.

"While the individual dies, the thought process passes from mind to mind and age to age. We are not ourselves only, we are also part of human experience and thought" (H. G. Wells). It is only little by little that a book is written, through consultation of authorities, copying, altering and adding a little to the work of and picking up hints from, the work of others, thinking out one point after another over weeks of time, writing of rough drafts and

gradually improving these and so on. There is evidence that along the years and across the oceans action and reaction ceaselessly continue in matter no less than in living organisms, further that the past is not done with in events interpreted physically and biologically, that there is no wild dance in matter and that consciousness is neither greater nor less than matter and energy, the ultimate nature of which physical and biological hypotheses are not capable of interpreting. "The universe," says Haldane, "is a spiritual world and not a dualistic universe of matter and mind." Yes, in so far as "the stirring of the ether by the finger of God" results, among all other phenomena, in consciousness which is determined, like all other phenomena of living or non-living organisms, by an evolutionary reaction to the environment.

"There is," says J. W. N. Sullivan, "no general agreement at present as to what science really does tell us about the material universe." "A light-quantum," says Eddington, "is big enough to fill completely the lens of the biggest telescope and small enough to enter an atom, and the theory of it may indicate that the universe finally is indeterminate." But all we can justly say, however, is that the quantum transcends our notions of space and time. It has the attributes of God. Einstein does not

doubt that in the next era of physical discovery complete determinism will again be triumphant. Planck, too, disbelieves in a "free-will" theory of the universe. George Thomson says: "It is conceivable that the behaviour of a critical electron in a critical atom might control the course of events in the brain and so the behaviour, and that such a view postulates a considerable difference between living and dead matter, or at least between conscious and unconscious. But the biologist has not found by observation evidence of behaviour which can be affirmed as not accompanied by excitation. In the explosion of hydrogen and oxygen do not atoms of water afford critical electrons?

We are told by Jeans that energy can exist in a number of forms and can change endlessly from one form to another, but cannot be destroyed, or created. That all existing energy must have existed from all time, although possibly in some form entirely different from its present form. That all the life of the universe may be regarded as manifestations of energy.

Energy has, then, attributes ascribed to God, unknowable, eternal. In every atom, just as in every complex of atoms forming a living cell, there is, then, the purpose of God; every atom is dynamic, not only moulded by the environment, but helping to determine it.

Hume says: "I ascribe to matter that intelligible quality, call it necessity or not, which the most rigorous orthodoxy does, or must allow to the will."

Of one thing there is certainty, viz. that scientific knowledge can extend life and happiness by education and prevention of disease, by recognizing and avoiding adverse forces of nature, by inventions for securing means of subsistence, utilizing and conserving sources of energy and controlling the birth-rate and so putting an end to war. Science relieves us of superstition and fear of punishment after death, and leads us to devote ourselves to the improvement of conditions on earth.

We have to reckon with inevitable natural forces; a meteor, such as the one that struck a hole almost a mile wide in a desert of Arizona, may destroy the city of London in the twinkling of an eye; volcanoes and earthquakes destroy cities, and tornadoes and floods and pestilences work destruction on good and evil alike; some criminals succeed and good people suffer; monsters and idiots are born; men have tortured, burnt and waged war in the name of religion.

Nature creates and destroys, indifferent to prayers, inscrutable, omnipotent, endowing us with joy in sky and sea, trees and flowers, the fruits of the earth, running waters, song of

birds, the play of animals and children, the love of a mother for her child, and kindly acts.

Man has it in his power to control breeding and prevent war, famine and pestilence. The methods of preventive medicine and economic science can carry men far on the road of making heaven upon earth, steadfastly pursuing these methods and teaching them by operation we can leave it to philosophers to contend "that the reality of space, time, matter is a four-dimensional mathematical continuum deduced from the study of three-dimensional matter existing in three-dimensional space, and in a flowing one-dimensional time" and "that self is immortal for space, time and matter, and all else are contained in it, it is itself the basic reality" (G. T. Hemens).

To repeat the argument given on the first page : all progress is made and tested by experimental operations. "Theory should be expressed in terms of concrete quantities of which we have experience, and transcendental space is not one of these."

"We are not living in the world to discover final truth," wrote Lord Haldane, "there is no such truth. What we find is always developing itself and assuming fuller forms. Of knowledge, we can at best master only a fragment. But if that fragment has been reached by endeavour that is sufficiently passionate, the

struggle towards it yields a sense of quality, of quality in the very effort made, which stands for us as being what we care for beyond everything else, as being for us truth, whatever else may not be certainly truth. And so life is not lived in vain, though in the ends attained it may seem to have failed."

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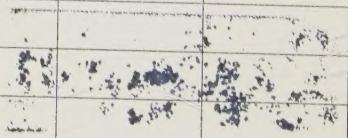

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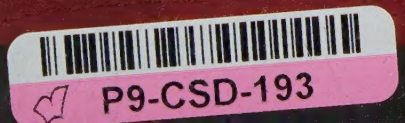
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